ponderating; we may conclude that the latitude at which the change of phase takes place shifts with the season, and that its average position is not far south of Lisbon.

The good agreement of our formulæ with the observed facts encouraged me to deduce the vertical component of force. Measured downwards it should be

$$\sin 2u \sin (t + \lambda)$$

if the cause of the disturbance is outside the earth, but

$$-\tfrac{3}{2} \sin 2u \sin (t + \lambda)$$

if the cause of the disturbance is inside the earth.

Both expressions have their maxima and minima coincident with those for the northerly components of horizontal force, a fact which finds its confirmation in actual observation. They also show the phase of the vertical force to be the same for each hemisphere and not to change as with the horizontal force. But there is an important distinction: while the vertical force has its maxima and minima coincident with the maxima and minima of horizontal force at latitudes greater than 45°, in the equatorial regions the maximum of horizontal force ought to be coincident with the minimum of vertical force, and *vice versâ*, if the cause is outside the earth's surface; the opposite should be the case if the cause is inside.

At Greenwich the maximum of northerly force takes place at 7 p.m., the minimum at noon; the maximum of vertical force takes place at 7 p.m., the minimum at 11 a.m.

At Bombay the maximum of northerly force takes place at 11 a.m., the minimum at 9 p.m.; there is a very decided minimum of vertical force at 11 a.m; but there is no pronounced maximum; two minor maxima occur, one at 6 a.m. and the other at midnight.

As far as these results go they give an emphatic answer in favour of the supposition that a great part at any rate of the disturbing currents lie outside the earth's surface, a view which Prof. Balfour Stewart has often supported in the last few years. The results seem to me very encouraging, and I hope soon to be able to make use of more material and to obtain more accurate expressions for the various forces concerned.

If we make use of the actual observations of Bombay and Greenwich, we may calculate for each hour the intensity and direction of the currents which would produce the disturbance. This has been done, and the results have been collected in a table.

It is very remarkable how very nearly at the same local hours the currents flow north and south at Bombay and at Greenwich, namely, at 4 in the afternoon and between 7 and 8 in the morning. It is curious, moreover, to find how very quickly the current turns through the meridian: at Bombay, at 3 o'clock, it flows at an angle of 15° from the east, and at 5 already it flows due west, and remains almost unaltered in direction till 5 o'clock in the morning. At Greenwich the currents turn much less sharply, but they always flow east when the currents at Bombay flow west. The system of currents indicated is that approximately shown by the equations given in the paper, the phase, however, being different. Along the meridian on which the local time is 4, the currents flow from the equator towards the north; they turn round in our latitudes towards east and west, join on either side again to go south, where the local time is 7.30 in the morning, and come back along the equator.

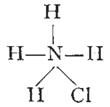
The strength of the currents is approximately of the same order of magnitude as the currents we are accustomed to send through our vacuum-tubes, but as the thickness of layer through which they are distributed must be very large compared to that on which we experiment, the current-intensity at each place is very small, far too small to cause luminosity. The currents, on the whole, are weaker at Greenwich than at Bombay, but, while they almost vanish at one time at Bombay, making the ratio of the strongest to the weakest current equal to 73, that ratio is only 3½ at Greenwich. The minimum at Greenwich in the early morning is as pronounced as the afternoon minimum, but much less so at Bombay.

On the whole, the numbers, both as regards direction and intensity, show such a remarkable regularity that there is good hope of obtaining a good mathematical representation of their distribution.

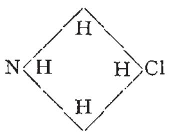
CHEMICAL AFFINITY AND SOLUTION

IN 1878 I read a paper to the Royal Society of Edinburgh, in which I stated my opinion, based on the results of a considerable number of experiments, that chemical combination solution and suspension of solids, such as clay, in water differ in degree only, and are manifestations of the same force; and that there seems to be a regular gradation of chemical attraction from that exhibited in the suspension of clay in water up to that exhibited in the attraction of sulphuric acid for water, which we call chemical affinity. Further, I stated that the attraction of chemical affinity is not, in all cases, at any rate, exhausted when a definite compound is formed, but has sufficient power left to form solution or suspension compounds. In 1881 I read another paper on chemical affinity and atomicity, in which I went a step further, and endeavoured to show that the theory of valency as usually held was incorrect in assuming chemical affinity to act in units or bonds, and insufficient to account for the various phenomena of varying atomicity, or valency, molecular compounds, crystallisation, solution, alloys, &c., and that all these varied phenomena were simply due to the chemical affinity of the elementary atoms, and that the difficulties disappeared if we got rid of the idea of the indivisible units of chemical affinity, and considered it as a whole acting all round, and spreading out, so to speak.

As an illustration of my views, I considered the compounds, HCl, NH_3, and NH_4Cl. In HCl we have two monovalent elements combined, and their chemical affinities completely neutralised or satisfied. In NH_3 we have N considered as a trivalent element satisfied with three monovalent elements. Now these two completed, neutralised or satisfied compounds combine with one another to form the third compound, NH_4Cl. How is this? The usual answer is that N sometimes acts as a pentavalent atom, and in this particular case does so, and the compound is represented graphically thus:



I pointed out that this explanation was most unreasonable, and to me, indeed, incredible, because it supposes that N, which has usually such a weak affinity for Cl, can nevertheless decompose the HCl into its constituent atoms, and fix the atom of Cl to itself. While on the other hand the Cl leaves the H, for which usually its affinity is so great, and unites itself to the N, for which usually its affinity is so small, and this while the atoms are in such close proximity, as they must be in a molecule, and with so many hydrogen atoms allied with it. My explanation was simply this. The affinity of the Cl acts on all the four atoms of H, and the affinity of the N does the same; and thus the whole molecule is held together, and may be represented thus:



I did not, however, exclude the idea that the Cl and N react on one another to some extent, but the *main* cause of the combination is as stated above.

Since these papers were read chemists seem to me to be coming more and more to my views in this matter. Thus Pattison Muir in his "Chemical Principles," says: "It seems to me that a most important step will be made if the bond theory of valency is generally abandoned; with it will go all those quasi-dynamical expressions, the offspring of loose and slipshod ways of thinking which have gathered round that strange anomaly, a unit of affinity employed as a variable standard for measuring nothing." Further, he says, in reference to the behaviour of acetic acid vapour when exposed to a high temperature: "If this is so, we evidently have a series of substances beginning with solution of salts or gases in water and proceeding through crystallisation and acetic acid vapour at low temperature, which connects mechanical mixtures on the one hand with stable gaseous compounds on the other."

Again, Professor Armstrong, in his address to the Chemical Section of the British Association at Aberdeen last year, says that in his view molecular compounds are held together by what, for want of a better name, he calls surplus, or residual affinity. In view of these and many other similar expressions of opinion, all tending in the same direction, I may perhaps be excused for again bringing forward the subject.

In the present paper, however, I shall confine myself mainly to the subject of solution, for two reasons. First, because it seems to me that if we can satisfactorily account for this part of the subject, the remainder will be easily and naturally explained; and, second, because from a study of Thomsen's researches on thermo-chemistry, as given in Muir and Wilson's recent work on that subject, I have obtained data which seem to me almost to demonstrate the truth of my views on the subject of solution.

In my paper of 1881 I explained solution to be due to the affinities of the constituent elements of the body dissolved for the constituent elements of the solvent. Thus NaCl dissolves in water because of the affinity of the Na of the salt for the O of the water, and of the Cl of the salt for the H of the water. These affinities not being strong enough to cause double decomposition, an indefinite compound is formed having the properties of what we call a solution. If this explanation be correct, we should expect that the relative strengths of the affinities of Na, O, Cl, and H should have an effect on solution, and that if we substituted another metal for Na whose affinity for Cl and O was greater or less, we should have a corresponding change in the solubility of the salt. If, for instance, this other metal had greater affinity for Cl and less for O, we should expect the salt to be less soluble, because the Cl would be held more firmly, and could not act so energetically on the H of the water, while the action of the metal on the O of the water would also be less. Now it may be admitted generally that the heat evolved in similar chemical operations is a measure of the chemical affinities of the elements concerned, or at least of their relative affinities. With these explanations, let us consider some of Thomsen's results. He finds as the result of numerous experiments that as the atomic weight of the metal increases in similar compounds of Mg, Ca, Sr, and Ba,

(1) Heat evolved in production of MCl_2 *increases*
(2) ,, ,, MO *decreases*
(3) ,, solution of MCl_2 ,,
(4) Solubility of MCl_2 in water ... ... ,,

These results apply to the alkali metals also.

To make these considerations plain, consider the following table:—

Metal		Heat of formation of chloride		Heat of formation of oxide		Heat of solution of chloride
Mg	...	151,010	...	146,000	...	35,920
Ca	...	169,820	...	130,930	...	17,410
Sr	...	184,550	...	128,440	...	11,140
Ba	...	194,740	...	124,240	...	2,070

Now the order of solubility of these chlorides is exactly as these results would lead us to expect, $MgCl_2$ being most soluble, and $BaCl_2$ least so, while $CaCl_2$ and $SrCl_2$ are intermediate; and the whole result is exactly what we should expect if my explanation of solution be correct. The chloride of the metal whose affinity (as measured by the heat evolved) is greatest for Cl, and least for O is the least soluble. Again, let us take the following series of elements in which the heats of combination with equivalents of either Cl or O gradually decrease (excepting Na for O), but that of Cl much faster than that of O, so that after passing Al the heat of combination of one equivalent of O is greater than that of Cl, and consider the action of the chlorides towards water:

NaCl	Soluble.
$MgCl_2$	,, but decomposed on evaporation.
$AlCl_3$	,, forms crystals with water, and decomposed on further heating.
$SiCl_4$ PCl_3 PCl_5	In contact with water, more or less quickly decomposed.
SCl SCl_4	Instantly decomposed in contact with water.
Cl gas	Dissolves in water, which it slowly decomposes on exposure to sunlight. Also at low temperature combines with water, forming compound $Cl5H_2O$. The behaviour of this gas is interesting, becouse it brings gases under the same principle of solution.
KCl	Soluble.

We have thus a regular gradation of change, from simple solution through double decomposition to solution again, according as the affinities of the elements for Cl and O vary. Thus solution appears as a periodic function of the elements.

Let us take another case, where the affinities of the elements for Cl and O again regularly decrease, but where the affinity for the O diminishes faster than that of the Cl, and note the result. The following group of elements represents this case:

NaCl	Soluble.
CuCl	Insoluble, or nearly so.
$CuCl_2$	Soluble.
AgCl	Insoluble.
AuCl	,,
$AuCl_3$	Soluble.

Now it will be observed that Cu, Ag, and Au have a small affinity for O compared to what they have for Cl; especially is this the case with Ag, and when these elements combine with only one atom of Cl, the chloride is insoluble; the affinity of the single atom of Cl for the H of the water, combined with the small affinity of the metal for the O of the water, is too weak to produce solution; but as soon as one or more atoms of chlorine are taken up, the compound becomes soluble through the increased affinity acting on the water.

All this is quite consistent with the view of solution I have proposed. In truth, this view is the most simple and natural explanation of the facts. There are not sufficient data to be obtained to trace these actions through all the various groups and series of elements, but there are numerous indications that they are regular recurring phenomena. I need only mention the analogous behaviour towards water of the chlorides of P, As, Sb, Bi and S, Se and Te.

I have chosen the chlorides to illustrate the principles of solution because of the simplicity of their composition and action, and also because the data are more complete for them than for other salts, but the same principle can be traced through all.

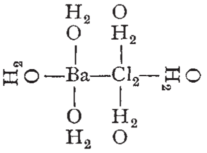
Let us consider, however, for a moment the solution of the oxides. In this case, as the metal is already combined with O, it is not likely to have so much effect on the O of the water. We see, however, the same action taking place. Thus take the following group and their heats of combination and solution:

Metal		Heat of formation of oxide		Heat of solution of oxide
Mg	... ...	146,000	... ...	2,960
Ca	... ...	130,930	... ...	18,330
Sr	... ...	128,440	... ...	29,340
Ba	... ...	124,240	.. ...	34,520

Now again we find that the oxide which has the greatest heat of formation is the least soluble, because the elements are held more firmly together, and less affinity is left to act on the water elements. Thus MgO is almost insoluble, while BaO is the most soluble of the group, and CaO and SrO intermediate. This order is the inverse of that of the chlorides, as the heat of formation is also inverse.

Many examples of the close relationship between the heats of formation and the heats of solution might be given. For example, if we neutralise the hydrates of the above oxides with a solution of HCl, we find the heat evolved approximately the same in all cases, being about 27,600 units. At first sight this appears very curious, seeing their affinities (as measured by heat evolved), for Cl and O vary so much and inversely; but the explanation is obvious enough. The heats of solution of the various compounds decomposed and formed exactly compensate for the variations in the heats of combination; what is lost in one way is gained in another.

Closely connected with solution is the subject of crystallisation. This also is most satisfactorily explained, if the principle I contend for be admitted, and regular structure necessarily follows. For instance, in such a compound as $BaCl_2\,6H_2O$, the atoms of the molecule must be arranged somewhat after the following fashion:



There are many other points connected with this subject, but as the data I can obtain are fragmentary, I shall content myself at present with indicating the direction of my inquiries.

(1) The affinities, measured as before, of the series Na, Mg,

Al, Si, P and S, for Cl, regularly diminish if we take the amount for one atom of Cl in each case; but if we take the actual maximum amount of Cl with which each element in the series combines, a very different result comes out, because while Na combines with one atom of Cl, Mg combines with two, and Al with three, and so on. This leads us to make a distinction between the intensity and quantity of chemical affinity, so that while the *intensity* of affinity in this case regularly diminishes, the *quantity* rises to a maximum in Al, and then diminishes towards S. There is thus a spreading out of affinity which lowers its intensity, and in this there seems to me a gradual approach to solution. I have traced the same phenomena in some oxides, and it is interesting to note that the atomic weight of Al, whose affinities for Cl and O are nearly equal, is almost exactly midway between the atomic weights of O and Cl. It is, so to speak, the point where the two curves of affinity cross one another. On the one side the affinity for Cl relatively to that for O increases, and on the other side decreases. This may throw some light on the peculiar properties of Al. Fe, which is in many respects analogous to Al, and has an atomic weight about twice that of Al, and almost midway between Cl and Br, shows somewhat similar relations towards Cl and O. It is also to be noted that while the maximum affinity for Cl is at Al, that of O is at Si. It would be interesting to trace curves of intensity and quantity for other elements such as H and S. Much light might be thrown on many chemical facts.

(2) If we take the heats of combination of Cl, Br, or I, with any element, the law seems to be that the amount of heat diminishes as the atomic weights of Cl, Br, and I increase, modified, however, by the atomic weight of the element with which they combine. Thus, take what may be called the normal case, viz. combination with hydrogen, we have

Atomic weight of Br =	80	of I =	127
,, ,, Cl =	35·5	Cl =	35·5
Difference ...	44·5		91·5
Heat of combination HCl =	22,000	of HCl =	+ 22,000
,, ,, HBr =	8,440	HI =	− 6,040
Difference ...	13,560		28,040

Now, 44·5 : 91·5 : : 13,560 : 28,040 almost exactly. With Al again the above differences are as under—

Heat of combination $AlCl_3$ =	160,980	of $AlCl_3$ =	160,980
,, ,, $AlBr_3$ =	119,720	AlI_3 =	70,590
Difference ..	41,260		90,390

Now it is evident these are not exactly in same proportion as the H compounds, and with Na and K compounds the discrepancy is even greater, but still near enough to suggest the general law as stated above.

(3) If the explanation given of crystallisation be correct, we may go a step further. If we take water alone without any salt in solution, there will be, in my view, attraction between the H_2 of one molecule and the O of another, and *vice versâ*, and if the heat of the liquid be diminished sufficiently, that attraction will cause cohesion of the molecules, and will produce solid water or ice, the regular structure of which is caused by the symmetrical arrangement of the atoms. This again leads on to solids in general, for there is little doubt that atoms of the same kind have affinity one for the other; and thus the various conditions of matter, solid, liquid, and gaseous, may be due to chemical affinity of the constituent atoms, modified in various ways by the kinetic energy of the system.

It will thus be seen that my view of chemical affinity is quite opposed to the idea of its being a sort of arbitrary force acting in units or bonds, but I consider it acts between all atoms of matter, whether of the same or different kinds in varying degrees of intensity and quantity, producing combination of more or less stability, graduating from the so-called mechanical mixture of clay and water up to the irresolvable molecules of the permanent gas, condensing by its action the gas into the liquid, and the liquid into the solid, chemical compounds being combinations in definite proportions of more or less stability. In fact, in this case as in all others, there are no hard and fast lines in Nature, but every phenomenon graduates by almost imperceptible degrees into another.

W. DURHAM

THE JAPANESE NATIONAL SURVEY AND ITS RESULTS

DURING the past five years a work of great national and scientific importance has been proceeding in Japan; little has been heard of it in Europe, and none of its results have been visible amongst us in England until within the last few months. The Japanese National Survey, under the superintendence of Dr. Naumann, formerly Professor of Geology in the University of Tokio, has during the period above mentioned been steadily progressing; it has revealed hitherto unknown features of the country, and has thrown a flood of light on its geography, geology, and resources, actual and possible. A period has now been arrived at in the history of the Survey: its Director, after five years' labour at this particular work, and as many more in the Chair of Geology in the University of Tokio, returns to Europe, leaving the task to be carried out by the Japanese whom he has trained. Some tangible results of the work have, as already mentioned, been for the first time placed before the European public. In the rooms of the Royal Geographical Society might a short time ago be seen by any one who desired to do so a series of maps, printed and manuscript, with numerous plans, illustrations, and sketches, exhibited by Dr. Naumann, and representing to some extent the work of five years. Samples of these were also to be seen at the Exhibition of Geographical Appliances in Great Marlborough Street, amongst others an orographic map of Japan, and several illustrations—one of the mountain summits in the neighbourhood of the active volcano Asamayama being especially striking. The present, then, seems a suitable time for describing the Survey, the work it has set before it, that which it has succeeded in doing so far, and the effect of its work on our knowledge of the country.

When Dr. Naumann laid before the Japanese Government, about six years ago, the plan for a national survey, it was based mainly on economical considerations. It was pointed out that by means of such a survey the resources of the country, hitherto undeveloped, and to a considerable extent unknown, would be investigated systematically. At the commencement of the undertaking there were hardly any maps in existence that could be utilised with safety. The work was facilitated by the materials derived from a Japanese astronomical-geodetic survey carried out at the beginning of the present century, which fixed the position of the coast-line and the courses of some of the main roads. The coast surveys of the English Admiralty, also, and of the navies of other countries, as well as the few results of the trigonometrical survey of Japan, were found of use. But the interior of the country, in all that related to orography and geology, was still a *terra incognita*. In every other respect those rough Japanese compilations of older map-work of a mediæval type, though worked out by the application of some of the principles of European cartography, were totally insufficient. Hence at the outset it was necessary to undertake a topographical survey, so that not only matter, but also space, became the object of investigation. From the beginning the necessity of combining observations with measurements was emphasised. Inasmuch as the economical position of the country depends on agriculture, special attention had to be paid to the relations between the qualities of the soil and its cultivation. Hence the Survey started with three departments intrusted with field-work—one topographical, the second geological, and the third agronomical. A fourth, the chemical section, was created to investigate and test the materials collected by the geological and agronomical sections as to their composition and technical applicability. The plans laid before the Government, and approved, placed the scale of the maps, which were to be published in three series corresponding to the three divisions of the Survey—one topographical, one geological, and one agronomical, at 1 : 200,000. The maps were to be 0·456 × 0·277 metres for publication, and each series was to contain ninety maps, each of which corresponded to half a degree division, reckoned on the meridian of Greenwich. Two editions, one in English and one in Japanese, were to have been published. The scale for the field-work was 1 : 50,000. Subsequent experience demonstrated the substantial accuracy of these plans. It is of course essential in surveys like this that the various divisions should work side by side, and advance with equal and regular steps. But a consequence of the conditions under which work of this kind is conducted in Japan was that this co-operation, which was so necessary to